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COMPUTER ENHANCEMENT OF HIGH RESOLUTION ELECTRON MICROGRAPHS CONTAINING WEAK PERIODIC INFORMATION*

by

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Using image processing methods and Fourier synthesis techniques similar to those mentioned by Nathan (1970), it has been possible to enhance weak periodic information contained in electron micrographs obtained from what might be characterized as less than ideal thin films. This paper describes the results of such an experiment and illustrates the potential afforded by these computer techniques in an ultrastructural analysis of similar type objects.

In the present work a {111} crystal wafer of silicon was subjected to an oxidizing atmosphere at $1050^{o}C$ producing the following reaction: $3Si = XO_2 \rightarrow Si + 2SiO_X$. The wafer was then chemically thinned to obtain a wedge-shaped film and examined in a high resolution 100kV transmission electron microscope. Selected area diffraction patterns appeared in general to be typical of an amorphous medium, but evidence for weak Bragg maxima could be found. Experimentally obtaining a lattice fringe image of the reminant Si crystal was expected to be extremely difficult, if at all possible. However as demonstrated below, it has been possible to recover and enhance a weak periodic signal from this apparently partially transformed material.

Lattice resolution experiments were performed in the usual way. Images were obtained at an electron optical magnification of $\sim$ X400,000. The area of interest is shown in Fig. 1 and its associated diffraction pattern in Fig. 2. In obtaining images the objective aperture was positioned so that the $\pm$ 220 maxima were included.

Optical densities of an area ($\sim 30\text{Å} \times 30\text{Å}$) were measured and encoded. The microdensitometry was done at a total image magnification of $\sim$ X2,000,000 with a 25μm spot. A computer displayed image of the digitized area is shown in Fig. 3.

The optical density data were Fourier transformed and, using the original diffraction pattern as guide, a spatial frequency filter was defined to separate the desired periodic image from the random image (both are shown in Fig. 4). Amplitudes and phases spatially corresponding to the transmitted and $\pm$ 220 Bragg maxima were then re-transformed to form a three-beam reconstructed lattice image (see Fig. 5). It has been possible to computer display these intensities at magnifications in excess of X75,000,000 (1.5cm $\equiv$ 2Å) with little loss in contrast and hence image detail.

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REFERENCE

1. Nathan R, 1970, Proc 28th Annual Meeting of EMSA, Houston (Baton Rouge: Claitor's Publishing Div) pp 28-29.

FIGURE CAPTIONS

Fig. 1 High resolution micrograph of Si-SiO_X film. Area enclosed in box was digitized and enhanced.

Fig. 2 Selected area diffraction pattern corresponding to thin film imaged in Fig. 1.

Fig. 3 Computer displayed image of digitized area. Grey scale has been stretched to enhance periodic contrast.

Fig. 4 Fourier transform of digitized area and pictorial representation of spatial frequency filter (lower right).

Fig. 5 Computer display of the three-beam reconstructed image.

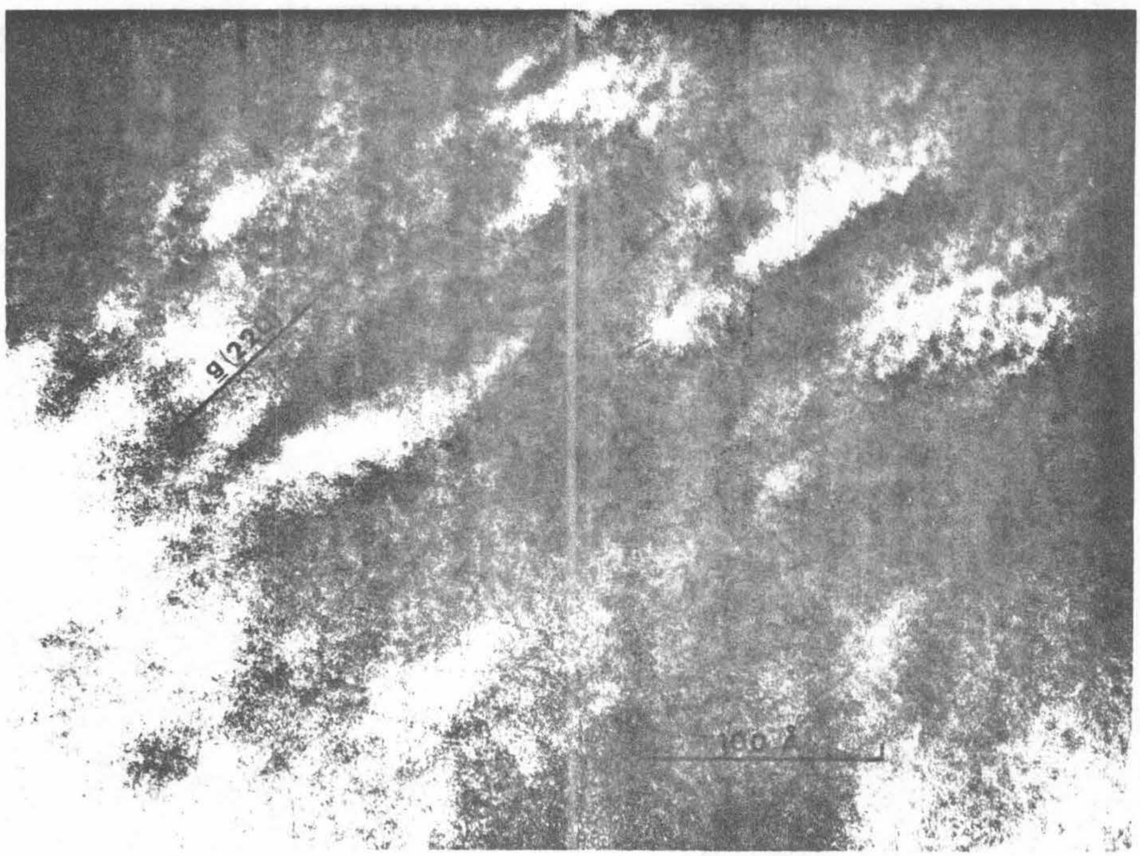

Figure 1

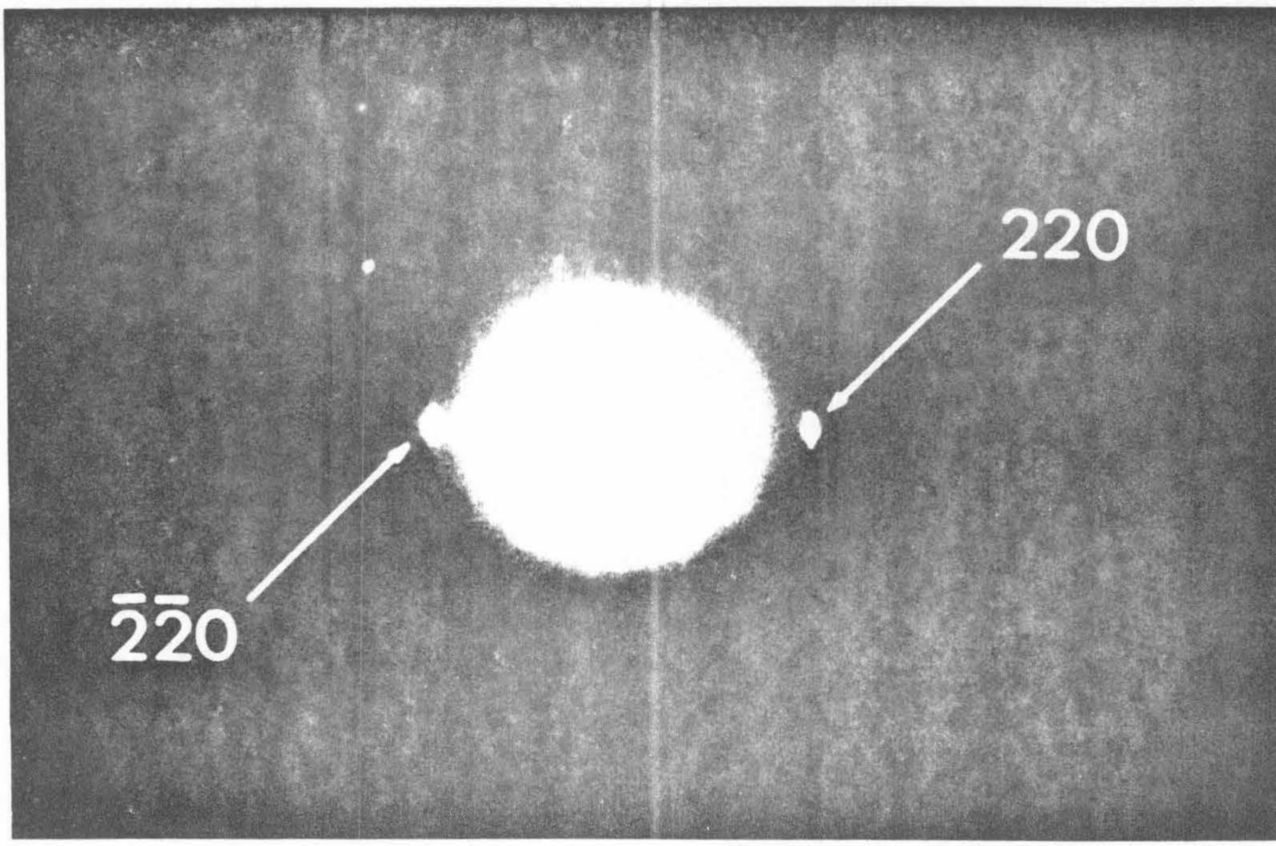

Figure 2

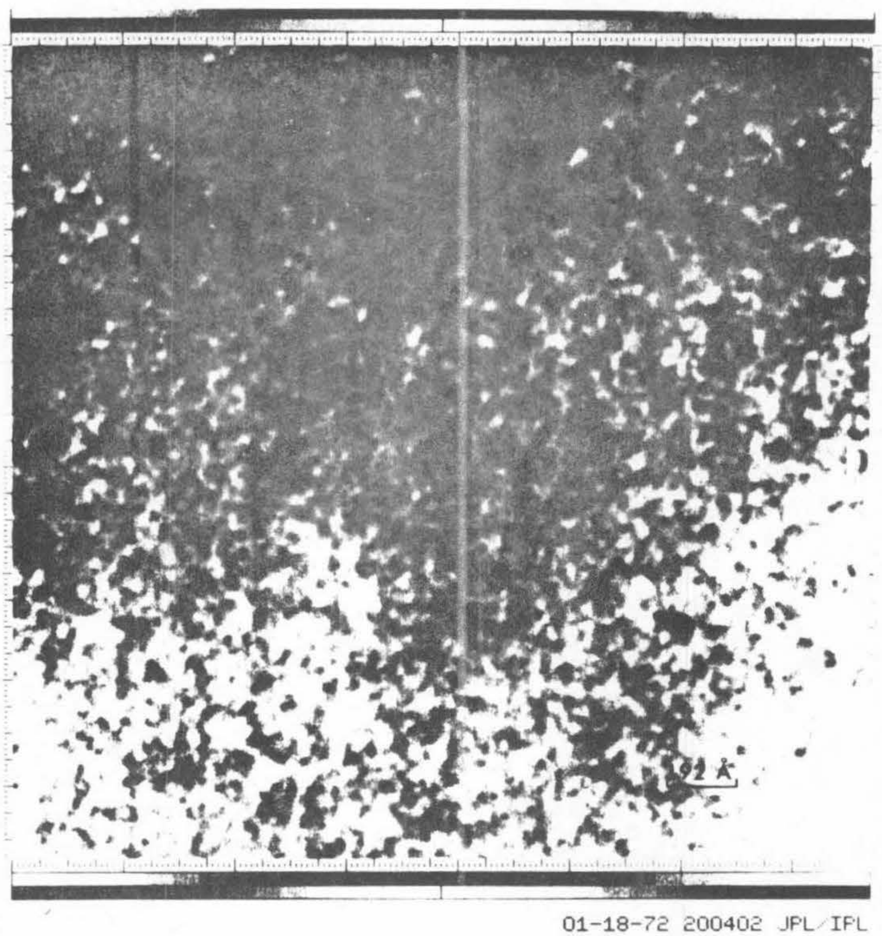

Figure 3

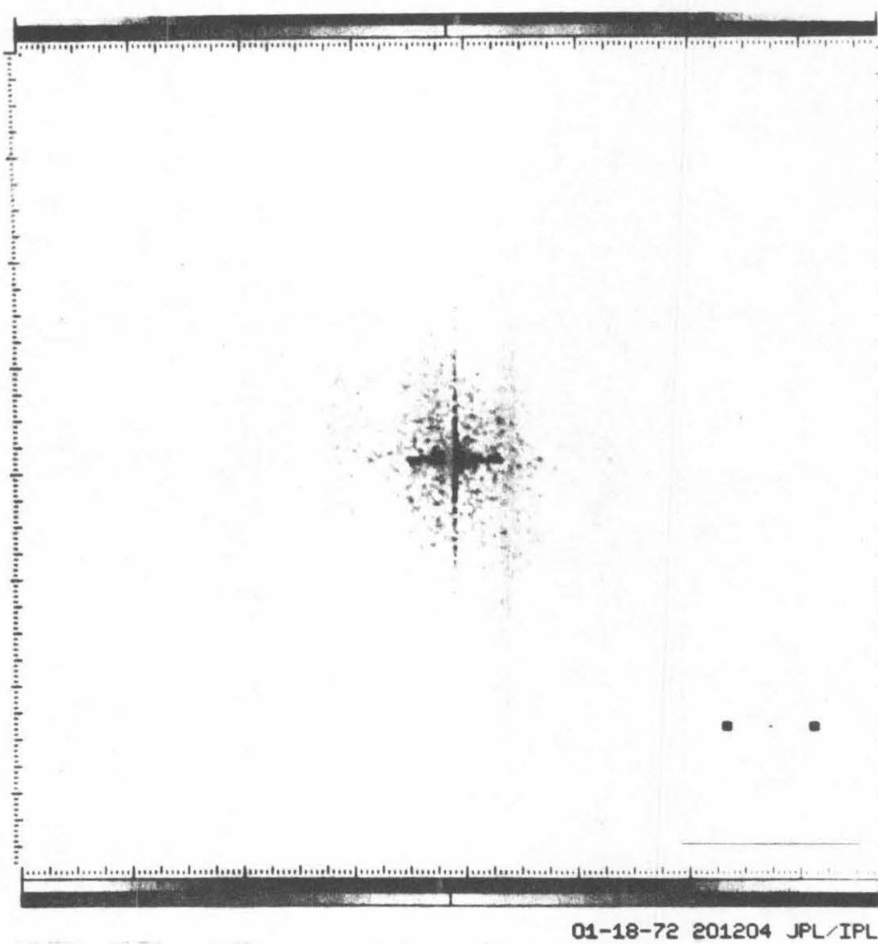

Figure 4

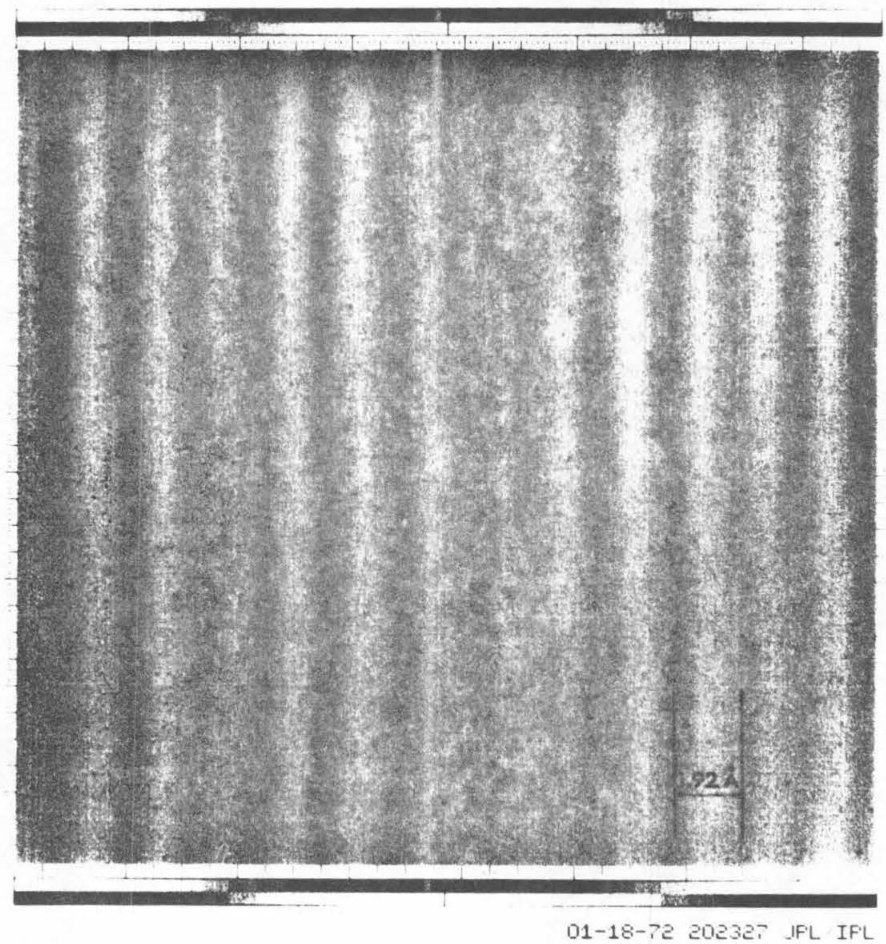

Figure 5